Chapter 11. Extension of HAZUS to Other Natural Hazards

11.1 Vulnerability to Natural Hazards

There are a variety of natural hazards that can cause significant damage to both the built and natural environments. The impact of these types of events, which include earthquakes, floods, hurricanes, tropical storms, tornadoes, volcanoes, tsunamis, landslides, and droughts, can be devastating and in extreme cases, such as the volcano in Pompeii, can destroy an entire population. In addition to damage to buildings and building contents, natural hazards can destroy crops, forests, and farmland, can undermine the infrastructure that is vital to the function and well being of the community, can cause significant monetary losses, casualties and disease and can have a destabilizing effect on the local or regional economy. When we talk about the **vulnerability** of a region to a natural hazard, we are talking about how susceptible the region is to damage, losses, and casualties.

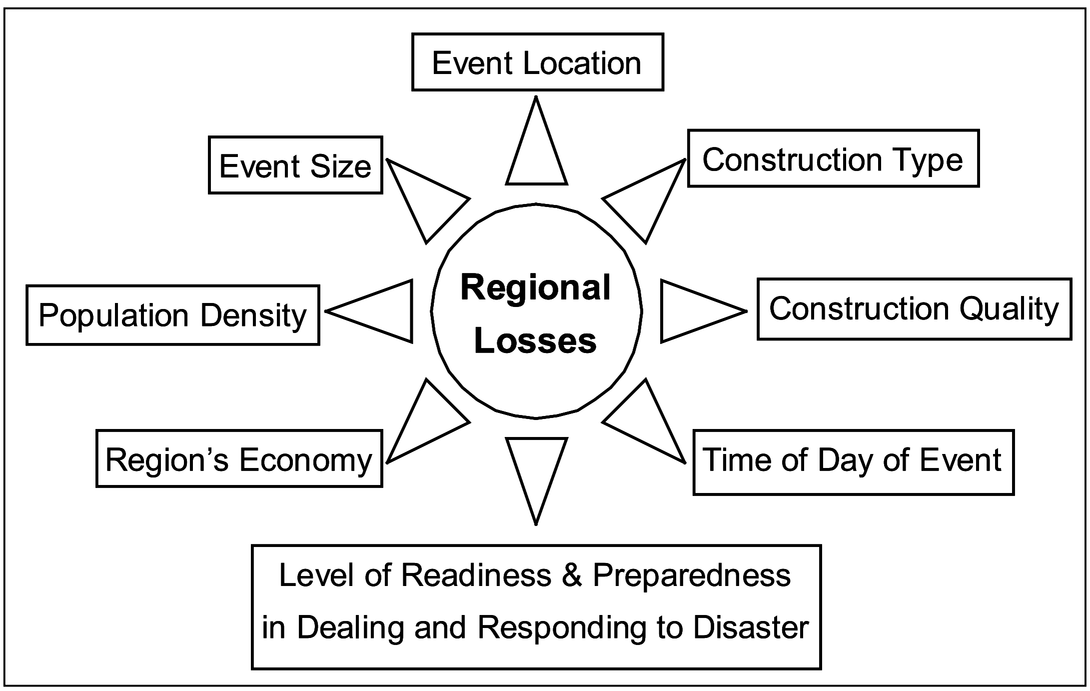

Figure 11.1 Factors that contribute to the regional vulnerability

Damage and losses depend not only on the type of natural hazard but also to a great extent upon the density of the population; the type, spatial distribution, and quality of construction; and the socio-economic makeup of the region (Figure 11.1). If an earthquake occurs in an unpopulated region, there will be little to no effect on regional infrastructure and little likelihood of loss of life. However, if the same earthquake were to occur near a large city then one could expect significant damage and monetary as well as social losses. As the world has become progressively more urbanized and people have moved to and settled in densely populated metropolitan areas, earthquakes occurring near these urban areas can result in very high losses. The Northridge earthquake and Hurricane Andrew illustrate the impact of natural disasters in high-density environments. Poorer regions with inexpensive non-engineered construction are more vulnerable and can expect heavier damage than regions that have large numbers of new buildings that are designed and constructed to modern codes. If the local economy is highly dependent on one or two types of business or industry, and these are destroyed, high unemployment can occur, resulting in a very slow recovery. To better understand vulnerability to natural hazards, it is necessary to discuss the types of damage that occur in these events.

11.2 Damage From Hurricane, Tornado and Flood

Many of the issues that are important in the assessment of damage and losses due to earthquakes are applicable to hurricanes, tornadoes and floods. Certain types of buildings and lifeline facilities are more vulnerable than others. Vulnerability can depend to some extent on the location of the facility but damage also has a random character about it. Damage can occur to structural elements, non-structural elements or to the contents of a facility. Damage to a facility can also result in secondary consequences such as fires and hazardous materials releases. All three of these hazards can affect a large region and can inflict long-term economic hardship on a community. These natural hazards, like earthquakes, can also cause injuries and deaths. The inventory that would be needed to perform a regional loss estimate for one of these hazards is much the same as that required to perform a loss estimate for earthquakes. An understanding of the types of damage that occur in hurricanes, tornadoes and floods will serve to illustrate this point.

11.2.1 Hurricanes

Hurricanes are severe storms (with sustained wind speeds over 120 km/hr) that begin over tropical seas. Hurricanes pick up strength over the ocean where they are fueled by evaporation of water and tend to lose their strength as they move inland. In the United States, the Gulf and Atlantic coasts are the areas that are affected by hurricanes. In addition to high winds, hurricanes can cause inundation as a result of storm surge (a rise in the level of the sea). While earthquakes can cause injury and death to livestock and can cause damage to crops and other vegetation, particularly if there are landslides, floods or fires, the losses are likely to be small in comparison to losses to the built environment. Losses can also occur to vehicles, farm equipment, trains, and boats as the result of hurricane event.

Wind is one of the main damaging characteristics of hurricanes. Wind speeds as high as 320 km/hr have been recorded (Alexander, 1993). Wind severity can depend on the location of a structure with respect to the density of other buildings, since winds tend to be more severe in open terrain. Structures can collapse as a result of very high wind pressures; however, a large percentage of the losses occur as a result of water damage. In Hurricanes Andrew and Iniki, 85% and 59%, respectively, of the houses suffered significant water damage to their interiors (Crandell et al., 1993). Once the roof or a portion of the roof has been destroyed, or windows and doors have been broken, the contents of a structure are very vulnerable to water damage. Damage occurs not only as a consequence of direct exposure to high winds, but also because of wind blown debris (or missiles) that impacts structures. In areas very close to the coast, inundation can exacerbate damage that results from the wind.

Small residential structures are vulnerable to roof damage. Gable roofs are more susceptible than hip roofs, and certain types of roof covering (e.g. composition shingle) are more vulnerable than others (e.g. gravel). A common problem is that roofs do not have positive connections to counteract the uplift forces that result from the winds, thus roof members can become detached from the walls.

Similar to their behavior in earthquakes, high-rise structures can experience a great deal of non-structural damage from loss of exterior cladding and windows. Broken glass can occur due to missiles or due to interstory drift. In Hurricane Alicia, 80% of glass breakage was due to missile impact (Alexander, 1993). Exterior cladding and parapets often are inadequately supported or inadequately attached to the structural system to withstand the forces of the wind.

Hurricanes can cause extensive damage to lifelines. Electric power supply systems sustain some of the most extensive damage after hurricanes. The damage to the system can be so great that it takes days to bring minimal service on-line. After Iniki there was complete service interruption on the island of Kauai (Zadeh et al., 1993). Loss of electric power can affect the operation of other lifeline systems such as water and wastewater treatment facilities, gas transmission lines and communications lines and facilities. After Hurricane Hugo little damage occurred to power plants and sub-stations but transmission lines and transmission line support structures were badly damaged. Transmission lines with metal support structures performed well in comparison to those with wood poles. Electric power distribution systems were also badly damaged, with the majority of damage being attributed to falling trees downing distribution lines (Cook, 1991).

Roads and bridges are mainly affected by the accumulation of debris on the surface. Similar problems occur with airport runways. Roadway signs and signals can be blown down which affects the delivery of emergency relief. Near the coast, bridges or roads may be damaged by inundation.

Communications transmission towers and dishes are vulnerable to the high wind loads that occur in a hurricane. Damage to telecommunications networks is expected to be similar to electric power distribution systems. If phone lines are above ground, falling trees may damage lines. In Hurricane Andrew, almost 100% of the drop lines, the line from the distribution lines to the service connection, were destroyed (Zadeh et al., 1993). It should be noted that in Hurricane Hugo, the post storm performance of the telephone system was relatively good, since most of the lines were underground (Cook, 1993). While long distance service may be undamaged, it can be unusable because of damage to local phone lines.

Underground water and gas pipes are not significantly affected by hurricanes except by occasional uprooted trees, so the main performance reduction to water systems is due to loss of power. This affects the operation of pumps and equipment in treatment plants. Loss of electrical power also affects the operation of wastewater treatment plants.

In conclusion, the inventory collected to estimate losses from hurricanes is similar to that needed to estimate losses from earthquakes. Additional characteristics may be needed such as type of roof (hip or gable), locations and value of farm land, density of development, and the locations of structures relative to the extent of storm surge. These are summarized in Table 11.1.

11.2.2 Tornadoes

Tornadoes, rapidly rotating columns of air, are found in the central, southeast and northeast United States. Wind speeds can be in excess of 400 km/hr. Tornadoes can form over dry land or can be generated as a result of hurricanes. Tornadoes can be essentially dry accompanied by dust and debris or they can be accompanied by rain or hail. They can occur individually or in families. Tornadoes may lift off the ground and touch down in some random pattern as they travel. They tend to cause the most damage where they touch down, and damage tends to occur in patches.

Damage from tornadoes, similar to hurricanes, occurs as a result of high wind pressures or by airborne objects. The types of damage are also similar. The inventory required to estimate losses from tornadoes, as summarized in Table 11.1 is similar to that for hurricanes.

11.2.3 Floods

Flood damage can occur as a consequence of riverine flooding or coastal flooding. Riverine flooding occurs when streams and rivers overflow because of excessive rainfall or snowmelt. Coastal flooding can result from large storms such as hurricanes that cause large waves or storm surge. The damage from coastal flooding can be more severe than that from riverine flooding because of the added force of waves. Other factors that affect the severity of damage are depth of flooding, the velocity of the floodwaters, duration of flooding and the presence of debris in the water. The location and elevation of the property with respect to the source of flooding determines the depth of flooding that can be expected. One of the major factors in assessing potential losses from inundation is the location of properties with respect to flood zones.

A large portion of the losses in floods occurs to building contents. Losses in floods are higher in properties with basements since basements often contain expensive items such as water heaters, heating and air conditioning units and many have been finished for use as extra living spaces. In some cases if there is a warning of flooding, moving valuable contents to upper floors can reduce losses. Losses to properties can be greatly reduced if buildings are raised on stilts or berms or if floodwalls or levees protect the property from flooding. Thus it is important to understand if “flood resistant” measures have been taken.

As with hurricanes and tornadoes, losses to vehicles, farm equipment, trains and boats can be significant. While flood damage can be minimized if areas prone to flooding are not developed, floods can cause severe damage to vegetation and agricultural land. Therefore land use is an important characteristic in assessing potential losses.

Inventory collected for assessing losses from floods is similar to that required for assessing losses from earthquakes. Additional attributes that you will need to collect are the locations of flood zones, elevation of the facility and evidence of flood resistant measures.

11.3 Key Factors in Estimating Losses from Natural Hazards

As has been discussed in the previous sections, the inventory required for estimating losses from different natural hazards has common elements. For all of the hazards discussed (earthquakes, floods, hurricanes and tornadoes) you must first determine the size and location of the event with respect to the region you are studying. The impacts will be more severe if the event is large and close to an urban area, if the dominant types of construction are vulnerable, and if the region is not well prepared. Impacts are also related to the type of economy in the region and the ability of certain sectors of the economy to rebound from production and inventory losses. Table 11.1 compares inventory for estimating losses from earthquakes, hurricanes, tornadoes and floods.

Table 11.1 Key Factors for Estimating Regional Losses From Natural Hazards

	Earthquake	Hurricane	Tornado	Flood
Hazard Considerations				
• Size of event	✓	✓	✓	✓
• Location of event	✓	✓	✓	✓
• Type of soil	✓			
• Topography	✓	✓	✓	✓
• Type of terrain (open or built-up)		✓	✓	
• Flood potential	✓	✓	✓	✓
• Tsunami potential	✓			
Buildings				
• Type of structural system	✓	✓	✓	✓
• Location of structure	✓	✓	✓	✓
• Height of structure	✓			✓
• Square footage of structure	✓	✓	✓	✓
• Age of structure	✓	✓	✓	✓
• Occupancy or use of the structure	✓	✓	✓	✓
• Building code design standards	✓	✓	✓	✓
• Potential for hazardous material release	✓	✓	✓	✓
• Cost per square foot for replacement	✓	✓	✓	✓
• Type of roof (e.g. hip or gabled)		✓	✓	
• Roof covering (tile, shingle, gravel or		✓	✓	
composition)				✓
• Existence of a basement				
Transportation Lifeline Systems				
• Types of components (e.g. bridges, tunnels,	✓	✓	✓	✓
cranes)	✓	✓	✓	✓
• Locations of components	✓	✓	✓	✓
• Amount of component (e.g. miles of	✓	✓	✓	✓
roadway)	✓	✓	✓	✓
• Age of components	✓	✓	✓	✓
• Characteristics of components (e.g. concrete or asphalt road)				
• Cost of replacement				

Table 11.1 (cont.) Key Factors for Estimating Losses From Natural Hazards

	Earthquake	Hurricane	Tornado	Flood
Utility Lifeline Systems				
• Types of components (e.g. pipes,	✓	✓	✓	✓
substations, treatment plants)	✓	✓	✓	✓
• Locations of components	✓	✓	✓	✓
• Amount of component (e.g. miles of pipe)	✓	✓	✓	✓
• Characteristic of specific components (e.g.		✓	✓	
cast iron or clay pipe)	✓	✓	✓	✓
• Above or below ground transmission lines	✓	✓	✓	✓
• Age of components				
• Cost of replacement				
Other Inventory				
• Agricultural products and livestock		✓	✓	✓
• Vehicles, rolling stock and boats		✓	✓	✓
Socio-Economic Factors				
• Population density	✓	✓	✓	✓
• Income, age and ethnicity of population	✓	✓	✓	✓
• Numbers of homeowners and renters	✓	✓	✓	✓
• Type of economy	✓	✓	✓	✓
• Employment in different economic sectors	✓	✓	✓	✓
• Business inventory	✓	✓	✓	✓

11.4 Accessing Supplemental Hazard Maps

A number of supplemental hazard maps are shipped with the **HAZUS** software. When you aggregate a region, you will be asked if you want to include the supplemental hazard data in the aggregation. If you indicate yes, the data will be downloaded from the CD and copied to your hard drive at that time.

If, on the other hand, you decide to download the supplemental hazard maps at a later time, use the following procedure. Go to the **File** menu and click on **Aggregate Multi-Hazard Data**. You will be asked to insert a CD in the drive (see Figure 11.2). Click the **OK** button. If you have the wrong CD you will be prompted to try again. Note: depending on the size of your region, it could take from 15 minutes to over an hour to download and aggregate the supplemental data.

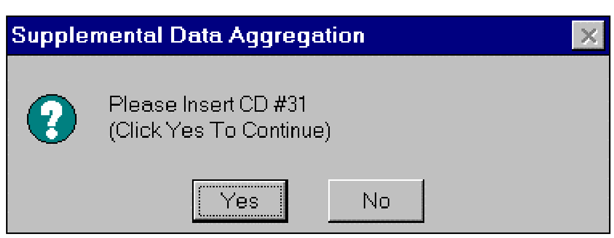

Figure 11.2 Prompt to insert CD when downloading supplemental hazard maps.

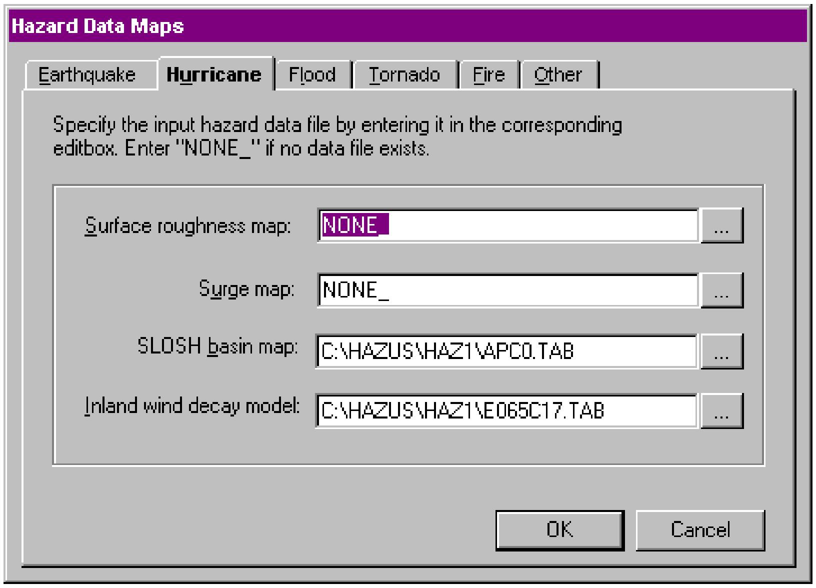

Figure 11.3 Hazard Data Maps window.

To view the maps, click on the **Hazard|Data Maps** menu and the window in Figure 11.3 will appear. Using the tabs at the top of the window, specify the maps you are interested in. In some cases, such as with SLOSH basins or inland wind decay models, multiple maps will be available for your use. To view which maps are available, click on the **…** button at the right of the list box and a window listing all of the maps, such as the one shown in Figure 11.4, will appear. Select the map you want to view and click **OK**. To view the maps, use the **Map** menu.

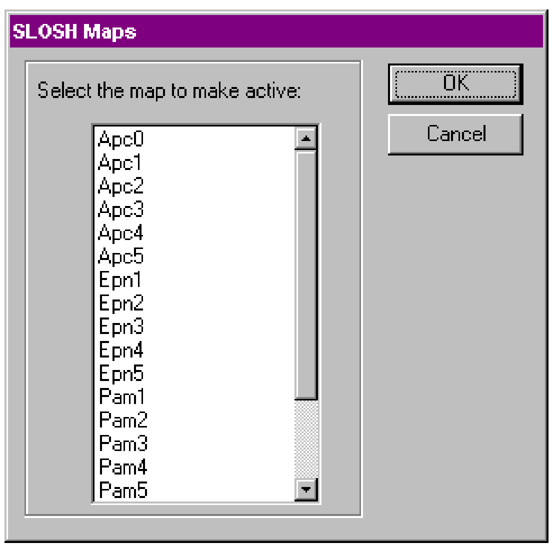

Figure 11.4 Window listing available SLOSH maps.

11.5 Hurricane Data Maps

SLOSH Basin maps (Sea, Lake, and Overland Surges from Hurricanes) outline the land areas expected to be inundated by hurricane surges. These maps are named according to the SLOSH Basin ID and hurricane category they represent. For example, FMY3 represents the surge from a Category 3 hurricane on the Fort Meyers, Florida basin. The surge (in feet) specifies the elevation of water above the National Geodetic Vertical Datum (NGVD) and **not** the depth of flooding. The surge value compared to the actual ground elevation **will** provide the depth of flooding. The National Oceanic and Atmospheric Administration (NOAA) Technical Report NWS 48 of April 1992 describes the development of these maps. Table 11.2 lists the Basin ID, the Basin Name and the states it affects. These files are located on the Supplemental CD-ROM in the \SURGE directory.

Table 11.2 SLOSH Basin Coverage
(Polar Coordinate System except where noted)

Basin ID	Basin Name	States Covered
APC	Apalachee Bay (Apalachiacola), FL	FL
BOS	Boston Bay, MA	MA, ME, NH
BPT	Sabine Lake, LA/TX	LA, TX
BRO	Brownsville, TX	TX
CDR	Cedar Key, FL	FL
CHE	Charleston Harbor, SC (Elliptical)	GA, SC
CHP	Chesapeake Bay, DE	DC, DE, MD, NC, NJ, PA, VA
COF	Cape Canaveral, FL	FL
CRP	Corpus Cristi, TX	TX
EBP	Sabine Lake, LA/TX (Elliptical)	LA, TX
EHT	Pamlico Sound, NC (Elliptical)	NC, VA
EPN	Pensacola, FL (Elliptical)	AL, FL
ETP	Tampa Bay, FL (Elliptical)	FL
EYW	Florida Keys, FL	FL
FMY	Fort Meyers, FL	FL
GLE	Galveston Bay, TX (Elliptical)	LA, TX
HNL	Island of Oahu (Honolulu), HI	HI
ILM	Wilmington, NC	NC, SC
LFT	Vermillion Bay, LA	LA
MIA	Biscane Bay (Miami), FL	FL
MSY	New Orleans, LA	LA, MS
NYC	Long Island Sound, NY	CT, MA, NY, NJ, RI
PAM	Panama City, FL	FL
PBI	Palm Beach, FL	FL
PNS	Pensacola, FL	AL, FL, MS
PSX	Matagorda Bay, TX	TX
SJU	Puerto Rico	PR
SSI	Brunswick, GA	FL, GA, SC

The National Hurricane Center's Inland Wind Decay Model displays the Maximum Envelope Of Winds (MEOWs). These MEOW maps are separated into three regions; the Gulf of Mexico, the Northern Atlantic coast and the Southern Atlantic coast. The files are named **ABBBcDD.*** where,

A	is the region specification: **E** for Southern Atlantic Coast **G** for Gulf Coast **V** for Northern Atlantic Coast
BBB	is maximum one minute sustained wind speed, in knots, of the hurricane. There are four possible values: 65, 85, 105, and 125
c	is a placeholder
DD	Is the forward speed of the hurricane, in knots. There are six possible values: 8, 12, 17, 22, 30, and 40.

The Wind_Spd value is the expected sustained surface wind speed (mph) at a location assuming the storm travels the minimum distance between the coastline and that location. The \HURR directory of the Supplemental Data CD-ROM contains this data.

11.6 Flood Data Maps

The Flood Insurance Rate Map (FIRM) is based on National Flood Insurance Program (NFIP) Q3 Flood Data. It shows the outline of the flood plains at a county level. Table 11.3 contains the zone classification descriptions. These files are found on the Supplemental CD-ROM in the \FIRM directory and are specified as FLQxxxxx.* where xxxxx is the county FIPS code.

Table 11.3 Q3 Zone Classifications

Classification	Description
A	Areas inundated by 1% annual chance flooding where Base Flood Elevations (BFE) have not been determined.
AE	Areas inundated by 1% annual chance flooding where BFEs have been determined.
A0	Areas inundated by 1% annual chance flooding (typically sheet flow on sloping terrain) where average depths have been determined to range from 1 to 3 feet.
AH	Areas inundated by 1% annual chance flooding (typically ponding) where average depths have been determined to range from 1 to 3 feet.
A99	Areas inundated by 1% annual chance flooding for which no BFEs have been determined. This area is to be protected from the 1% annual chance flood by a Federal flood protection system under construction.
AR	Areas inundated by flooding for which BFEs and Average depths have been determined. This is an area that was previously and will again be protected by a Federal flood protection system and whose restoration is Federally funded and underway.
V	Areas inundated by 1% annual chance flooding with velocity hazard (wave action) where BFEs have not been determined.
VE	Areas inundated by 1% annual chance flooding with velocity hazard (wave action) where BFEs have been determined.
X500	Areas inundated by 0.2% annual chance flooding; areas inundated by 1% annual chance flooding with average depths of less than 1 foot or with drainage areas less than 1 square mile; areas protected by levees from 1% annual chance flooding.

Similar to the FIRM maps, the Floodway map outlines those areas required for the discharge of the base flood. The classification descriptions can be found in Table 11.4. These tables are found in the same directory as the FIRM maps and are specified as FLFxxxxx.* where xxxxx is the county FIPS code.

Table 11.4 Floodway Classifications

Classification	Description
FW	Areas that includes the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation by more than a designated height (typically Zone AE).
FE	Areas within a community usually bordering a stream that has more restrictive floodplain development criteria imposed by governing body (town, city, etc.) than required for participation in NFIP.
SEA	Areas within a community usually bordering a stream that has more restrictive floodplain development criteria imposed by the state than required for participation in NFIP.

Coastal Barrier Resources System Areas (COBRA), are those regions where flood insurance is not available for structures newly built or substantially improved after the Coastal Barrier date. COBRA maps are provided for display purposes only and are available only for certain coastal regions. These areas are specified by the COBRA_IN code in the COBRA field. These files a located with the other flood data and are specified as FLCxxxxx.* where xxxxx is the county FIPS code.

11.7 Elevation Data Maps

The Elevation Contour maps are based on the USGS Digital Elevation Model (DEM) data (see the **Fire** tab in Figure 11.3). The maps are contoured at 10 meter intervals and are available by county. The DEM data is based on a 1^{o} x 1^{o} quadrangle using a 3 arc-second grid. The maps are located in the \DEM directory of the Supplemental Data CD-ROM specified as DEMxxxxx.* where xxxxx is the county FIPS code. More information concerning the methods of developing the Digital Elevation Model can be found in the USGS Data Users Guide 5.

11.8 Land Use/Land Cover Data Maps

Land-Use/Land-Cover (LULC) maps are based on USGS data (see **Other** tab in Figure 11.3). They represent the characteristics of the land, indicating whether it is built-up land or tundra and forest. The original USGS classifications have been grouped into 11 categories in the NEWCODE field as shown in Table 11.5. The original data was retained in the LUCODE field. The LULC files are found on the Supplemental Data CD-ROM in the \LULC directory named as LUCxxxxx.* where xxxxx is the county FIPS code. Information concerning the development of the LULC data can be found USGS Data Users Guide 4.

Table 11.5 Land-Use/Land-Cover Classifications for the NEWCODE field.

Code	Description
11	Residential
12	Commercial Services
13	Industrial
14	Transportation, Commercial
19	Mixed Urban Use
29	Agricultural
39	Rangeland
49	Forest Land
59	Water
69	Wetland
99	Barren Land/Tundra

11.9 FEMA Shelter Data

Maps locating facilities within the state that are classified as FEMA shelters are located on the Supplemental Data CD-ROM in the \SHELTERS directory. These maps contain data concerning the building ownership, structure type, and other characteristics of the structure.

11.10 Street/Roadway Data Maps

These maps contain the surface street information at a county level. They are found in the \STREET directory of the Supplemental Data CD-ROM directory named as STRxxxxx.* where xxxxx is the county FIPS code. They list street names and road classifications where available.